

THE WORLD OF CHEMISTRY

Program #1

THE WORLD OF CHEMISTRY

Producer John Ketcham

Air Script: October 31, 1988

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Annenberg/CPB Project Logo and Music

Funder Credits

MONTAGE: Chemists at work in
labs, paints, cloth factory, ocean,
leaves

NARRATOR (MUSIC under):
These people are manipulating
molecules. They're trying to take crude
oil and turn it into new medicines,
brighter paints, stronger fibers and
fabrics. They're chemists. Central to
our way of life is their science,
chemistry. Not only can chemistry help
us understand the wonders of the natural
world around us and within us, but it
uses that understanding to produce
thousands of new products every year.
In this program and, in those that
follow, we'll be exploring The World of
Chemistry.

SUPER: THE WORLD
OF CHEMISTRY

THE WORLD OF CHEMISTRY OPEN: Montage, Music, Logo

RH in office

ROALD HOFFMANN (SYNC):

Welcome to the World of Chemistry, and welcome to my office, where I sit, and think, and teach, and occasionally read things other than chemistry. But can I get away from chemistry completely? Not if I think deeply or if I want to live, and I certainly want to do both. If I look in detail at the paper in this book, I see in it wood fiber, a natural product that's been processed chemically. I see the printer's ink, another chemical. And, more importantly, the marvelous thought of the poet. Deep down, that is chemical, too. He is thinking and feeling, to quote him, "with all the soul of my chemical reactions." Let me show you some of the other things that are chemical in this office. Here is a ceramic vase. Some clay has been changed into something useful and beautiful. Here is a mobile that my daughter gave to me one birthday. It's made out of painted styrofoam balls. There's chemistry in this tape recorder, in the shiny metal and in its circuit boards with silicon and plastics. There is chemistry in this tape, chromium dioxide on mylar, in a plastic case. There is chemistry everywhere. There are pigments that make that print beautiful. (cont.)

ROALD HOFFMANN cont:

There's chemistry in the minerals and in every molecule in that living cactus. And there is chemistry in this Louisville Cardinals T-shirt, signed by all the champs. If I look at the label, it reads, "50 percent polyester, 50 percent cotton," a blend, a mixture of two molecules, one synthetic, the other one natural. Come, let's explore this world around us, the world of chemistry, of the molecules that nature makes, and those that we make.

MONTAGE: Chemical reactions,
chemists at work in labs

NARRATOR (MUSIC under):

At first, the world of chemistry seems overwhelming, with its rooms filled with complex mazes of glass tubes and beakers, its miles of pipes and boilers, and its foreign language of strange symbols. The test tubes and equations are the tools chemists use to probe the nature of the world we live in. Wherever they look, they find chemistry in action.

MONTAGE: Volcanos,
hardened lava, crystals,
time-lapse of grass growing,
whale, microscopic organisms,
food, fabrics, drugs, paint,
plastics, batteries, cosmetics,
chemists at work

NARRATOR (MUSIC and NAT
SOUND under):

There is chemistry at work renewing the Earth's crust. As the lava cools, the rocks and minerals of the natural world reveal themselves. And there is chemistry in the living world, in plants, animals, from the gigantic to the microscopic. There's chemistry in the food we eat, and in the clothes we wear. It has been said that chemistry is the sensual science. It provides us with energy and with uncountable products we take for granted. It can increase our food supply and provide us with new pharmaceuticals. Our world is a chemical world, from the paint on our walls to the fibers in our fabrics. Cushions, seat covers, objects of art, all are, in one way or another, the products of chemistry. Chemistry is more than polymers, polyesters, polyurethane, polystyrene. It's sun lotion, batteries, even cosmetics. But how did all these things come to be? How did researchers, using the tools of their science, the glassware and instruments, unravel nature's secrets and make plastics in the first place? (cont.)

NARRATOR cont:

What gave them the idea? The whole process of discovery begins with questions, with people curious about their world, curious about how things work, and why things behave the way they do.

INTERVIEW: Dr. Jacqueline Barton, Columbia University

SUPER: Dr. Jacqueline Barton, Columbia University

DR. JACQUELINE BARTON (SYNC):
How do we convert from one structure into another structure? How do we take a material and create plastic? How does a cell take sugar and convert it into a substance which is a storehouse for energy? Why is it that when I eat something, that helps me think differently? So in different respects, the chemistry really is involved in how nature actually takes food and converts it into thought.

Volcanic eruption, shot
of earth from space

NARRATOR (MUSIC and NAT
SOUND under):

There are so many intriguing questions.
Where do we begin to find answers?
The easiest way to start is to step back
and look at the Earth itself.

INTERVIEW: Dr. Mary Good,
Allied-Signal Corporation

SUPER: Dr. Mary Good,
Allied-Signal Corporation

DR. MARY GOOD (SYNC):

The Earth is an interesting place.
There's lots of things here, right? We
have learned through long time to do
lots of things with them. I can do things
that are very good with them; I can do
things that are very bad with them. So
it's not the chemistry that's good or bad,
it's what I do with that and how I utilize
it.

Miners at work, factory
shots, salt fields

NARRATOR (NAT SOUND under):

What exactly is here in the Earth. What
is in the ores and minerals we dig up?
Thousands of years have been spent
learning how to find these riches,
extract, and then purify them. It must
be more complicated than just melting
rocks down and having steel pour out
the other end. If things were that
simple, civilization would probably be
more advanced. It took thousands of
years to move from the Stone Age to the
Iron Age, and the major steps taken
along the way were chemical ones.
Other things had to be added to molten
iron ore to produce steel. (cont.)

NARRATOR cont:

It took an art, a chemical art, to do that. Obtaining iron, steel, and the super alloys from iron ore is amazing, but getting aluminum from its ore -- bauxite -- is even more astounding. That process is only a hundred years old. And what we are able to do with ordinary salt is incredible.

MONTAGE: Salt

NARRATOR (NAT SOUND under):

Salt has been a human treasure since the beginning of history. Today its value comes not so much from the kitchen table, but from its use in the chemical industry, because salt is made of sodium and chlorine, as our series demonstrator, Don Showalter, will show us.

DS in lab

SUPER: Don Showalter

DON SHOWALTER (SYNC):

In this beaker is chlorine gas. See the green color that's in there. That's quite a poisonous gas. What I want to do is to heat a piece of sodium metal, get it nice and molten, and put it inside here, and let's see what happens. That's quite a reaction, huh? A lot of light. It gets more and more intense. There's a white crystalline material that has formed on the sides of the beaker. (cont.)

DON SHOWALTER cont:

That's sodium chloride, regular table salt. What we have done is to take two elements that are quite dangerous and combine them into a substance that is essential for life.

MONTAGE: Salt mines, salt fields, factory shots, water treatment plant, plastic wrap, oil fields

NARRATOR (MUSIC and NAT SOUND under):

Most of the salt we use comes from deep, cavernous mines, or from vast evaporating ponds. The chemical industry doesn't use salt. It transforms it into other substances. By passing an electrical current through a concentrated solution of salt water, we can make sodium hydroxide -- caustic soda -- chlorine and hydrogen. We use sodium hydroxide to break down wood pulp and make paper. We use chlorine to purify our water. And we can take chlorine, attach it to carbon and hydrogen, and make plastic wrap. But where do the carbon and hydrogen come from? They come from coal, and oil. What was in this slimy sludge, and what could be done with it? The first step was for chemists to separate crude oil into its pure compounds, which could then be used to make new compounds, and eventually, useful products. (cont.)

NARRATOR cont:

It took years for nylon, which was one of those products, to emerge from the laboratory and find its way to the department store shelf.

Archival nylon stocking
footage

(A crowd of screaming women)

INTERVIEW: Dr. Mary
Good cont.

DR. MARY GOOD (SYNC):

Most of the chemical industry in the United States today is based on petroleum. You really have a huge network from the raw materials which are primarily petroleum to the refinery situation, which is primarily the place in which you get starting materials. And those starting materials are then used to make petrochemicals. The petrochemicals then are used to make all kinds of things.

MONTAGE: Plastics, oil,
oil fields and rigs, ice,
water, mountains

NARRATOR (MUSIC under):

In order to produce plastic tubs and jugs, we had to first learn something about what was in the oil, and to do that, we had to learn more about its physical properties, melting and boiling. (cont.)

NARRATOR cont:

Matter, like oil or water, even iron, exists in three different states, as a solid, a liquid, or a gas. Water is probably the most well known example. Ice is a solid. It maintains its form. Water, like all liquids, conforms to the shape of its container. When it boils, water becomes a gas. No matter what state it's in, solid, liquid, or gas, it's still the same old water. These changes of state can be shown in almost any lab. Don Showalter is about to dip a flask of bromine gas into a canister of liquid nitrogen.

DS in lab

DON SHOWALTER (SYNC):

Now, what will happen at that temperature is that bromine should change state, so the gas should go into the liquid, and the liquid should go into the solid. So we see all three phases, all three states of matter in action. This is the bromine gas, the top part up here. The dark material now is the bromine liquid, and at the very bottom is the yellow solid of bromine. All three states of matter.

MONTAGE: Oil refinery and
graphic, chemical plant,
pollution

NARRATOR (MUSIC and NAT
SOUND under):

We can use our understanding of these states of matter to separate oil into its different components. If we heat the crude oil, as the temperature rises, first one compound evaporates, then another, and another. Each compound can be drawn off and then we can do something else. In another process, a chemical process, these compounds are broken, cracked by heat and pressure, to form new compounds. Now the oil is actually being changed. It's not the same old oil anymore. It's being changed, but not lost. In a chemical reaction, of whatever kind, photosynthesis or refining, matter is never lost. In ordinary chemical reactions, matter is neither created nor destroyed. This is a scientific law of central importance to chemistry. In this plant, the matter, the oil, is being changed on a large scale. All sorts of products are coming out of this plant: methane, ethylene, steam, smoke, and flame. But when everything is added up, the mass coming out will always equal the mass going in. That includes products and by-products. All of our raw materials are drawn from the earth, and that's where the products and waste end up, too. (cont.)

NARRATOR cont:

We can bury them in the ground. They might change, but they won't go away. The smoke and gases generated by this coal-fired electric plant are pumped into the air, and they don't disappear. They can come back as acid rain, or have other far-reaching effects. To understand these chemical reactions, we have to look at the basic constituents of matter, at atoms and molecules, and how they're arranged.

RH in office with models
of molecules

ROALD HOFFMANN (SYNC):

Look. Here is a methane approaching a silicon surface. Now methane is a common molecule, the main component of natural gas. And my friends have been bombarding surfaces like this one with methane and watching it fall apart into fragments. What I would like to know is where those fragments sit on a surface. Is it right on top of a silicon? Is it in a hollow? I'd like to know what it takes to move this fragment around the surface. Perhaps it could meet up with another fragment to make a molecule, a complex one, maybe a useful one. In the real world, deep down, where we must look at it, we see three-dimensional molecules. (cont.)

ROALD HOFFMANN cont:

Molecules are groups of atoms held together by bonds, which are represented here by these wooden sticks. We know the lengths of the bonds. We know their strength. We have learned that much and more about a world that, until a short time ago, was invisible.

Scanning Tunnelling
Microscope

NARRATOR (NAT SOUND under):

Today we can actually see the basic building units of all matter. We can actually see atoms. One device used is called the scanning tunnelling microscope. Robert Hamers remembers the first time he saw an atom.

INTERVIEW: Dr. Robert
Hamers, IBM

SUPER: Dr. Robert
Hamers, IBM

DR. ROBERT HAMERS (SYNC):

It was about two or three o'clock in the morning, and I was staring at this image, and I started to notice this regular pattern appearing, which I knew had to be the positions of the atom, and it just got better and better, and I was just elated. Eventually, tears came to my eyes because I was so happy, having worked on this day and night for so long.

Computer images of
the atom

NARRATOR (MUSIC under):

This is what Hamers saw, the atomic landscape of silicon. The electron clouds of each atom blend to form this scene. Different kinds of atoms can bond together, forming the molecules that make up matter. Being able to see firsthand how these atoms bond together will help confirm the models we have imagined. But despite this technology, we still need to build models of how we think molecules might look.

INTERVIEW: Dr. David
Pensak, Du Pont Company

Computer model

DR. DAVID PENSAK (VO/SYNC):

What you are looking at now is a computer graphics picture of DNA, the thread of life.

SUPER: Dr. David Pensak,
DuPont Company

What we're trying to understand, in any kind of a model, is exactly what's going on at the level whereby nature is doing whatever it is is happening. We cannot get down small enough (cont.)

Computer model

DR. DAVID PENSAK cont:

physically to see that, so what we have to do is try to simulate this in a way that will let us think about it in a creative manner.

Laser beam

NARRATOR (NAT SOUND under):

There are other ways of exploring the molecular world. One way is to use light, because what molecules do to light tells us something about their structure, as Don Showalter shows us.

DS in lab

DON SHOWALTER (SYNC):

The sample that we're going to examine is chlorophyll. I've mixed some grass with alcohol and chopped it up in a blender. The alcohol extracted the chlorophyll from the grass. Look what happens when the light passes through the chlorophyll sample? A band of light is removed. The chlorophyll molecule has absorbed certain frequencies of the visible light. This absorbed energy has lifted some of the electrons in the chlorophyll molecules to a higher energy level.

GRAPHIC, chemists at
work in lab

NARRATOR (MUSIC and NAT
SOUND under):

Understanding how atoms combine to
form molecules, and how molecules
combine, forming even larger
molecules, allows us to devise new ways
to make our own. In fact, chemists are
busy in their labs making about 2500
new and different molecules every day,
ones that have never existed before.

INTERVIEW: Dr. Bertram
Fraser-Reid, Duke University

SUPER: Dr. Bertram
Fraser-Reid, Duke University

DR. BERTRAM FRASER-REID
(SYNC):

All scientists measure things. They plot
graphs, they make predictions, and so
on. Chemistry does that, in addition to
which they make new things. They use
this raw data to make new compounds,
and I think this is very unique. Some of
these compounds are useful, to make
better clothing, to make better foods, to
make better controllable environment,
and so on.

Chemists at work on computer,
Greek stone carvings, willow
tree, archival photographs and
footage of chemists at work in
labs, aspirin

NARRATOR (MUSIC and NAT
SOUND under):

How do chemists make new molecules,
and why? It's often for a particular
reason, they design one to do a specific
job, like relieve pain and ease human
suffering. Hippocrates, the ancient
Greek physician, was known to have
prescribed chewing willow bark to
relieve pain. What was there about
willow bark? It turns out that willow
bark contains a certain chemical,
salicylic acid, a natural analgesic. In the
19th Century, chemists finally isolated
salicylic acid, analyzed it, and then
synthesized it in the lab. Later, a
derivative, acetylsalicylic acid, proved to
be more effective. Today, this synthesis
of aspirin is a fairly routine experiment,
as Don Showalter demonstrates.

DS in lab

DON SHOWALTER (SYNC):

I weighed out 138 milligrams of
salicylic acid. Let's see if I can transfer
it all into this small test tube. Good, it's
all in there. All right. Next thing I
must add is one drop of phosphoric acid.
That's used as a catalyst, to speed up the
reaction, huh? (cont.)

DON SHOWALTER cont:

And then, the other active ingredient now, major reactant, is acetic anhydride. I need to add point-3 milliliters of that. And we'll shake it up a little bit and mix up all the reactants, and then we need to heat it for five minutes at 90 degrees; we'll put it in there and heat it now for about five minutes. We'll take the test tube out of there with our mixture, and I want to add some cool water to that. All right, a little bit more. All right. Now we'll let it cool. And as the mixture now cools, we should see crystals form of acetylsalicylic acid. Okay, let's see if we can filter it now and see if we can recover any product, huh? And let's see if we got any aspirin out of there, huh? What we can do is turn off that suction, and I'll lift up that filter paper, see what we've got. Oh, look at that. There's the aspirin we made. Let's see if we can scrape it onto here so I can get a good look at that. Now that's acetylsalicylic acid.

Health: Archival footage,
computer graphics,
computer models

NARRATOR (MUSIC under):

The connection between chemistry and health has always been strong, and it's growing stronger. (cont.)

NARRATOR cont:

Our instruments and techniques of discovery are getting better, and our understanding of the molecular world is expanding. Now, chemistry stands at the threshold of making not just new molecules, but new molecules of life.

INTERVIEW: Richard
Heckert, Du Pont Company

SUPER: Richard Heckert,
DuPont Company

RICHARD HECKERT (SYNC):

Biotechnology is of interest to us because it is an extension of good, plain old organic chemistry, a very complicated extension of it. I think at this time it's particularly intriguing because we are beginning to understand life processes at the molecular level.

MONTAGE: Chemists at work
in labs, car factory, rocket
launch, computer models,
traffic, skyscrapers, nature,
microorganisms

NARRATOR (MUSIC and NAT
SOUND under):

Research into the chemistry of life will almost certainly lead to the development of new plants that grow faster, in harsher climates. New fertilizers will emerge, the hope being to feed an ever-expanding population. (cont.)

NARRATOR cont:

Chemistry studies the changes that take place in matter. Sometimes those studies are driven by simple curiosity; sometimes they are motivated by a desire to make the world a better place in which to live. As chemistry and the other sciences get closer to understanding nature's mysteries, new challenges will arise. For the past century, each wave of innovation has quickly succeeded the last. Yet the tide of chemical revolution also brought unforeseen consequences, like acid rain, or the threat to the ozone layer. Should the role of scientists go beyond discovery? Should they also be involved in making the vital decisions that impact society?

Chemists at work in labs

DR. GEORGE PIMENTEL

(VO/SYNC):

The people who have the expertise, who understand, in a very rational way, what are the options, what are the dangers, what are the benefits, must take a much more active role in helping educate the public. (cont.)

INTERVIEW: Dr. George
Pimentel, U.C. Berkeley

SUPER: Dr. George
Pimentel, U.C. Berkeley

DR. GEORGE PIMENTEL cont:
Far too few of us have actually been
willing to come out of the laboratory
and take on this very difficult task, but
we must do it, not in the interest of
chemistry but in the interest of society.

RH in garden

ROALD HOFFMANN (SYNC):
The plant world is green, all shades of
green. What I'd like to know is how
these plants take carbon dioxide, and
water, and sunlight, and transform them
into amino acids and carbohydrates and
the oxygen that I need. Well, I can look
at a leaf and zero in on the chloroplast,
which is where the action takes place,
and isolate out the beautiful green
chlorophyll molecules that trap the light,
and if I look deeper I see copper,
manganese, iron atoms, all crucial to
photosynthesis. It's a beautiful chemical
change, this business of trapping elusive,
seemingly unsubstantial light, and
transforming, using the energy of that
light, relatively simple building blocks
into the kind of complex molecules that
make this tree grow. People have found
out how it works. Why? Because we're
curious. (cont.)

ROALD HOFFMANN cont:

It's in the nature of human beings to be curious about the world around us, about ourselves. This is the ultimate driving force in chemistry, to know. What we don't know we may find uninteresting. Worse, what we don't know we may be afraid of. As we learn more about the world, the more interesting, the less threatening, the more beautiful it becomes.

Credits, Closing Montage, Closing Music

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